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Mass trapping of the overwintering generation stripped stem borer，*Chilo suppressalis*（Walker）（Lepidoptera：Pyralidae）with the synthetic sex pheromone in northeastern China

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Abstract：The suppressing effect of water traps baited with a 41∶5∶4 blend of *Z*11-16：Ald，*Z*13-18：Ald and *Z*9-16：Ald for mass trapping of the stripped stem borer（SSB），*Chilo suppressalis*（Walker）was evaluated in green rice production bases in Jilin Province of China in 2002 and 2003. The investigation showed that populations of the male SSB were reduced by 84.54% and 83.75% in 2002 and 2003 respectively，compared with the untreated control plots. The sex ratio（female∶male）of the SSB population in the trapping plots largely skewed to female. Also the female mating percentage and the density of the egg masses in the trapping plots was reduced significantly，compared with that of the control plots in both years. Correspondingly，the infestation levels of the withered leaf sheaths（WLS），dead heart（DH）and the white head（WH）plants destroyed by SSB larvae in 2002 and 2003 were notably reduced. The combined results indicate that mass trapping with the synthetic sex pheromone is a promising agent against SSB.

Key words：Rice pests；*Chilo suppressalis*；overwintering generation；sex pheromone；mass trapping

The stripped stem borer（SSB），*Chilo suppressalis*（Walker）（Lepidoptera：Pyralidae），is one of the most serious rice borers in temperate and subtropical Asia. The boring activities of SSB larvae in different stages of rice development cause different symptoms in rice plant，such as withered leaf sheaths（WLS），dead hearts（DH），and white heads（WD）（Hill，1983）. In most parts of Jilin，one of the northeastern provinces in China，there is only the overwintering generation and SSB adults mainly emerge from June to August. Recently，the population density has tended to outbreak in most regions due to the changes of rice variety and the cultural practice. Nowadays，farmers mainly depend on insecticides to control the pest. However，application of toxic chemicals may result in pest resistance to insecticides，destruction of beneficial insects，secondary pest outbreaks，environmental pollution and health hazards. Reduction of insecticide application is，therefore，of great importance. Among other means，use of sex pheromone may contribute towards achieving this goal. Since the main three components，（*Z*）-11-hexadecenal，（*Z*）-13-octadecenal and（*Z*）-9-hexadecenal，were identified from the female stripped stem borer（Nesbitt *et al*.，1975；Ohta *et al*.，1976；Tatsuki *et al*.，1983），several studies concerning population monitoring and mating disruption of the moth with the synthetic sex pheromone had been conducted（Tanaka *et al*.，1987；Casagrande，1993；Kondo and Tanaka，1994a，1994b，1995；Kojima *et al*.，1996；Yang *et al*.，2001），and the results were promising to manage the pest. In this study，we assessed the efficacy of SSB control by mass trapping with the synthetic sex pheromone in the green rice production bases in northeastern China.

1 MATERIALS AND METHODS

1.1 Experimental sites

The trials were carried out during the flight season of SSB overwintering generation in green rice production bases in 2002 and 2003. The bases are located in Gangyao and Shengshui villages，Liuhe County，Jilin Province，which is situated at 42°15′N，125°5′E. Both villages are surrounded by small hills. In two years，the pheromone treated fields（trapping plots）are ca. 100 hm^2 and 80 hm^2 in Gangyao and Shengshui，and the untreated control fields（control plots）ca. 50 hm^2 and 40 hm^2，respectively. The trapping and control plots were separated by at least 400 meters in order to minimize the immigration of gravid females from control plots into the trapping plots. Rice seeding beds were

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planted on April 1，and transplantation was completed on May 10. Farmers irrigated the rice fields by native spring water. The predominant rice variety grown in that area was " Tongyou 307 "，which was moderately resistant to the SSB. Throughout the season of the rice plants，the conventional pesticides were prevented from being used to control the SSB.

1.2 Pheromone trap

The synthetic sex pheromone was a mixture of（*Z*）-11-hexadecenal，（*Z*）-13-octadecenal and（*Z*）-9-hexadecenal（41∶5∶4）. The mixture of the three components and an antioxidant（BHT）were impregnated into a rubber septum. Green plastic basin（18 cm × 24 cm base and 16 cm height）was used as water trap，with one pair of opposite holes near the margin and the other pair in the wall 10 cm above the bottom of the basin. The rubber septum was suspended in the center of a piece of iron thread that crossed the marginal holes. Water containing washing powder，to reduce surface tension，was placed in each basin trap to a depth of 8 cm and the rubber septum suspended 1 cm above the water surface. Each basin trap was set up at a height of 0.5 m above the ground at the rice field boundary with three sticks placed in the pheromone treated rice fields from June 1 to August 10 in 2002 and 2003. And the traps were applied at the density of 30 per hm^2. The moths captured by the traps，except the marked traps，were counted and removed every 3 days. Each rubber septum was renewed every 20 days.

1.3 Estimation of SSB male populations and the water traps efficacy

In the trapping plots，10 water traps were marked to estimate the male population，which were about 50 m apart from each other. The caught moths were removed every day after counting. The same operation was carried out in the control plots. Each year，the whole trial periods from June 1 to August 10 were divided into 7 subperiods at 10-day intervals.

1.4 Estimation of sex ratio and female mating rate

During the peak flight season of the SSB moths in 2002 and 2003，at 4- or 5-day intervals 60 to 120 wild moths were collected by hand in the selected paddy fields in both plots. The caught moths were immediately immersed in 70% ethyl alcohol，and counted the female and male to estimate the sex ratio. The female moths were dissected under binoculars to check for the mating status by the spermatophore.

1.5 Investigation of egg masses

In order to investigate the egg masses and the injured rice stem plants，10 paddy fields were randomly selected in the trapping plots and 10 in the control，respectively. Counts of egg masses were made every 4 days over the 12 days period during the peak flight season of the SSB. In each selected paddy field，600 hills of the rice plants were randomly investigated for egg masses. The hatched egg masses were removed from rice plants after each investigation.

1.6 Investigation of the infestation levels of the rice plants

After 1 week of the SSB egg hatching peak period，600 hills rice plants were randomly examined across each selected trapping field for the withered leaf sheaths（WLS）caused by rice stem borer larvae，and so was done in the control plots. The total number of dead hearts（DH）and white heads（WH）were recorded respectively when their symptoms were stable. In addition，20 hills were randomly selected and investigated for the numbers of the tillers and panicles at the maximum tillering and heading stages in each selected fields in pheromone-treated and control plots，respectively.

1.7 Statistic Analysis

All data of the subsamples from a single plot were treated as one replicate. Pheromone trap catches were subjected to a log（x + 1）transformation to normalize the means. All rice plant damage percentages were transformed using arcsine square root to normalize the means. Comparisons between the trapping and control plots were made with a *t* test（SPSS，1999）.

2 RESULTS

In 2002，the trapped SSB male moths increased consistently from the first subperiod to the fourth one，and then decreased steadily，both in the trapping and control plots，so the fourth subperiod（from July 1 to July 10）was the peak flight season of the SSB. And the same trend was found in 2003 except the peak flight season of the SSB（from June 21 to June 30），which was a subperiod earlier than that of 2002（Table 1）. The catches were significantly fewer in the trapping plots than that in the control plots in both years. In addition，the population of the trapped SSB in 2003 was higher than that in 2002，regardless of the trapping plots or the control plots（Table 1）. But the reduction percentage and trap efficacy were almost the same.

Mean sex ratio（♀/♂）of the SSB in the trapping plots was significantly higher than that of the control plots in both years（$P < 0.01$）（Table 2）. In 2002，the sex ratio was 1.14 for the control plots and 3.96 for the trapping ones，and it was 1.12 and 3.84 in 2003 respectively.

During the peak flight season of the SSB moth，the mean mating rate of the females caught by hand in the trapping plots was also significantly decreased compared to the control（$P < 0.01$）（Table 2）. But the difference of the mean mating rate was not significant between 2002 and 2003，regardless of the trapping plots or the control plots.

Table 1 Trap catches of RSB male moths in trapping and control plots in 2002 and 2003 in Jinlin, northeastern China

Sampling date		Trapping plot[a]	Control plot[a]	% reduction[b]
2002	1 – 10 June	44	430	89.77
	11 – 20	77	711	89.17
	21 – 30	411	2 991	86.26
	1 – 10 July	868	3 962	78.09
	11 – 20	272	1 598	82.98
	21 – 31	123	752	83.64
	1 – 10 Aug.	31	171	81.87
		(260.86 ± 113.80)^{c*}	(1516.43 ± 543.04)^{c}	(84.54 ± 1.57)^{c}
2003	1 – 10 June	31	292	89.38
	11 – 20	249	1 728	85.59
	21 – 30	946	3 977	76.21
	1 – 10 July	645	3 276	80.31
	11 – 20	388	2 698	85.52
	21 – 31	157	1 084	85.52
	1 – 10 Aug.	108	663	83.71
		(360.57 ± 124.47)^{c**}	(1959.71 ± 526.23)^{c}	(83.75 ± 1.62)^{c}

[a] The male moths caught by 10 water traps every 10 days in trapping and control plots, respectively. [b] (Control-trapping)/control. [c] (Mean ± *SE*). * Significant difference between trapping and control ($P < 0.05$, $df = 6$) (Paired-Samples *t* test). ** Significant difference between trapping and control ($P < 0.01$, $df = 6$) (Paired-Samples *t* test).

Table 2 The sex ratio (♀/♂) and female mating rate in trapping and control plots in 2002 and 2003 in Jinlin, northeastern China

Sampling date		Sex ratio (♀/♂)		Female mating rate (%)	
		Trapping plot	Control plot	Trapping plot	Control plot
2002	3 July	4.07	1.15	26.67	67.50
	8	3.84	1.28	36.84	70.88
	13	3.64	1.14	35.23	73.42
	18	4.28	0.98	28.29	64.96
		(3.96 ± 0.14)^{a**}	(1.14 ± 0.12)^{a}	(31.76 ± 2.51)^{a**}	(69.19 ± 1.86)^{a}
2003	29 June	3.36	1.30	23.74	69.97
	2 July	4.03	1.15	56.75	85.78
	6	3.53	0.83	46.33	80.23
	10	4.45	1.21	34.45	72.21
		(3.84 ± 0.25)^{a**}	(1.12 ± 0.10)^{a}	(40.32 ± 7.16)^{a**}	(77.05 ± 3.65)^{a}

[a] (Mean ± *SE*). ** Significant difference between trapping and control plots ($P < 0.01$, $df = 3$) (Paired-Samples *t* test).

Three examinations of egg masses per 100 hills from July 1 to July 18 both in 2002 and 2003 were conducted in the trapping and control plots, and the difference between the plots in both years was statistically significant for the first two examinations ($P < 0.05$) (Table 3), just not so for the one on July 8 in 2003. The number of the egg masses per 100 hills in the trapping plots was well below the control (Table 3). However, the percentage of reduction of the egg masses per 100 hills in 2002 was significantly higher than that in 2003 ($P < 0.01$).

Based on the reductions in the trap catches, the female mating rate and the density of egg masses, the percentages of the injured rice plants consequently reduced (Table 4). Although the percentages of the WLS, DH and WH were all well low, the differences for each symptom between the two plots were extremely significant ($P < 0.01$) for 2002 and 2003. In addition, the percentages of the injured rice plants (WLS, DH and WH) in 2003 were also higher than that in 2002, but the difference was not significant.

Table 3 Number of egg masses per 100 hills rice plants in trapping and control plots in 2002 and 2003 in Jinlin, northeastern China

Sample date		Trapping plot[a]	Control plot[a]	% reduction[b]
2002	7 July	$0.2533 \pm 0.0776^{*}$	0.6614 ± 0.1599	61.70
	12	$0.3333 \pm 0.1028^{*}$	0.8333 ± 0.1626	60.00
	18	$0.0502 \pm 0.0175^{*}$	0.1298 ± 0.0274	61.33
		$(0.2123 \pm 0.0843)^{c}$	$(0.5415 \pm 0.2117)^{c}$	$(61.01 \pm 0.52)^{c**}$
2003	1 July	$0.4167 \pm 0.0669^{*}$	0.7333 ± 0.1130	43.17
	4	$0.2667 \pm 0.0619^{*}$	0.5000 ± 0.0527	46.66
	8	0.1500 ± 0.0524^{ns}	0.2333 ± 0.1130	35.71
		$(0.2778 \pm 0.0772)^{c}$	$(0.4889 \pm 0.1444)^{c}$	$(41.85 \pm 3.23)^{c}$

[a] Number of egg masses per 100 hills (Mean ± *SE*). [b] (Control-trapping)/control. [c] (Mean ± *SE*). ns: not significant. * Significant difference between trapping and control ($P < 0.05$, $df = 18$) (Independent Samples *t* test). ** Significant difference of the % reduction in 2002 and 2003 ($P < 0.01$, $df = 4$) (Independent Samples *t* test).

Table 4 Percentages of the injured rice plants (WLS, DH, WH) in trapping and control plots in 2002 and 2003 in Jinlin, northeastern China

Year	Treatment	Withered leaf sheath[a]	Dead heart[b]	White head[c]
2002	Trapping plot	$0.2053 \pm 0.0226^{**}$	$0.0084 \pm 0.0013^{**}$	$0.1050 \pm 0.0238^{**}$
	Control plot	1.0722 ± 0.1596	0.0206 ± 0.0040	0.4295 ± 0.1052
2003	Trapping plot	$0.4228 \pm 0.0878^{**}$	$0.0318 \pm 0.0015^{**}$	$0.2500 \pm 0.0301^{**}$
	Control plot	1.6852 ± 0.1085	0.0771 ± 0.0030	0.8623 ± 0.0970

[a] Percentage of the withered leaf sheaths (Mean ± *SE*). [b] Percentage of the dead heart plants (Mean ± *SE*). [c] Percentage of the white head plants (Mean ± *SE*). ** Significant difference between trapping and control plots ($P < 0.01$, $df = 18$) (Independent Samples *t* test).

3 DISCUSSION

The technique of mass trapping with pheromone had been widely used for the control of different insect pests (Howse *et al*., 1998). However, unlike coleopteran and dipteran pests, only a few examples of the successful application of pheromone-baited mass trapping of Lepidoptera had been reported (Beevor *et al*., 1993; Faccioli *et al*., 1993; Mafra-Neto and Habid, 1996; Isart *et al*., 1997). This may be due to the reasons, such as lack of highly efficient traps, problems of large insect populations and trap saturation, shortage of economically acceptable cost and unavailability of isolated experimental sites (Mafra-Neto and Habid, 1996; Howse *et al*., 1998). Control of insect pests by mass trapping is effective only when populations are low and where isolation precludes reinfestation (Madsen *et al*., 1976; Masden and Carty, 1979; Huber *et al*., 1979). In our study, the population of the SSB adults was relatively low and the experimental site was isolated, which were among the key factors helpful to the success of mass trapping.

The results of the significant drop in catches and a consequent change in sex ratio throughout the SSB flight season in the trapping plots obviously indicated that the female matings were greatly delayed because of the trap-out of the males. In addition, the small residual untrapped and newly emerging males may need to mate repeatedly with the virgin females. Torres-Vila *et al*. (2002) had summarized the experimental evidence that in many lepidopterous species the aging of virgin females has a detrimental effect on reproductive output, either by decreasing female readiness to mate and/or by reducing her fecundity and/or fertility. This is important in developing behavioral control strategies that use pheromones. In fact, the detrimental effects of the delayed mating on females were also found in field control experiments. In control of *Heliothis armigera*, the fertility of the eggs collected in mass trapping plots decreased 13.5%, compared with the control plots (Ge *et al*., 1997). And in *Ancylis sativa*, the fertility of the eggs in mass trapping plots decreased 82.8% (Shi *et al*., 1999). In our study, it is also possible that the detrimental effects of the delayed mating on SSB females occurred.

Mass trapping is seldom used in the developed countries to control the SSB, and they would rather prefer mating disruption to mass trapping, probably because of the dependence on the manual labor to install and maintain traps. In China, however, the manual labor is readily available and relatively inexpensive. Moreover, Jinlin Province is one of the most important green rice production bases in northeastern China, where the chemical insecticides are strictly prevented from being used. Because the technique of mass trapping is environmentally friendly, efficient, nonpoisonous, nonpolluting, and nonhazardous to the natural enemies, which meeting the demands of the green rice production, so it is more promising to use mass trapping to control the overwintering generation SSB in northeastern China.

In the present study, the technique of mass trapping was proved effective to control the SSB. However, it should be noted that in this study the egg masses density and consequent destroyed percentages are all well below the control threshold (Kondo and Tanaka, 1995). Further research is required to determine whether mass trapping using sex pheromone traps is a promising means of effectively controlling the SSB at higher density.

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性信息素大面积诱捕法防治东北越冬代水稻二化螟

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摘要：2002 **年和** 2003 **年，在吉林省柳河县绿色大米生产基地，开展了应用性信息素诱捕法防治越冬代水稻二化螟** *Chilo suppressalis* **的试验。与对照区相比，**2002 **年和** 2003 **年两年诱捕区诱蛾量分别下降** 84.54% **和** 83.75%**，雌虫交配率分别下降** 54.10%**和** 47.67%**；同时，诱杀区二化螟卵孵化率下降** 25.50%**，卵块密度也显著降低。**2002 **年二化螟雌雄性比由对照区的** 1.14 **上升为诱捕区的** 3.96**，而** 2003 **年由** 1.12 **上升到** 3.84**；诱杀区二化螟幼虫为害率，无论是枯鞘、枯心，还是白穗，也较之对照区显著下降，造成稻谷产量损失也明显降低。通过上述一系列评价指标表明性信息素诱捕法能有效控制东北越冬代水稻二化螟，可为东北绿色大米的可持续生产提供技术支持。**

关键词：水稻害虫；二化螟；越冬代；性信息素；大面积诱捕

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